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ASSESSMENT OF LEAN PERFORMANCE OF MANUFACTURING CELLS IN AN SME USING AHP

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ABSTRACT

Lean Manufacturing is a tool widely used in manufacturing enterprises in order to remove any sort of waste and maximize the efficiency. After the lean principles have been implemented in an enterprise, it is very necessary to measure the improvements with proper measurements of it. Hence a methodology is required by decision makers, which can successfully gauge the extent to which the lean manufacturing philosophy has been implemented. A large number of approaches have been used previously which can assess the lean practice implementation. One of such methods is the Lean Radar chart which graphically indicates the gap between the actual and ideal performances. A number of originations assess the performance of various departments by offering them rewards in order to produce a healthy competitive environment. The current research work deals with the application of AHP in order to assess and rank the lean performance of various manufacturing cells in an SME producing bicycle parts based on certain lean performance assessment parameters namely, Material Flow, Visual Control, and Metrics.

***KEYWORDS**: Lean Manufacturing, Lean Radar Chart, Analytical Hierarchy Process (AHP) & SME*

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INTRODUCTION

In the current research work, the lean performance is measured in an SME which deals with the manufacturing of bicycle parts. The concerned SME produces 5 different varieties of products and has got four major manufacturing cells where each cell is dedicated to the manufacturing of a specific family of products. The SME is relatively new and has been in operation for past six years. A Number of steps have been taken to implement lean manufacturing. In some enterprises, lean radial charts are used in order to find the gap between the benchmark performances and the actual performance. However, their main limitation is that they are poorly suited for making trade-off decisions in the case when one chart is greater in every variable than another on some variable, but less on others. In order to overcome the issue faced by other conventional assessment methodologies, Analytical Hierarchical Processing (AHP), is used in the current research work. AHP is used in this paper in order to compare and rank four manufacturing cells based on three parameters for lean performances, namely, Material Flow, Visual Control, and Metrics.

ANALYTICAL HIERARCHY PROCESS

Analytical hierarchical processing (AHP) is a tool which is widely used by researchers working in the field of decision making for selecting the best alternatives among a number of choices when the judgement has to be based on a wide range of parameters. It is basically a multiple attribute decision-making tool. The AHP technique makes a comparison of various parameters, or, available alternatives with respect to an alternative in a pairwise mode. In order

to complete this task, the AHP uses a basic scale of absolute numbers which has been proven in practice and validated by physical and decision problem experiments. AHP basically converts the preference obtained from individual experts into ratio scale weights which can be further combined into a linear additive weight for each available alternative. The result finally obtained is used to compare and rank the alternatives and hence simplifies the choice of the decision maker.

METHODOLOGY

The approach which was undertaken to apply AHP in order to compare and rank the various manufacturing cells based on the lean manufacturing assessment is described here.

Identification of Parameters for Lean Assessment

The following three parameters were considered in order to compare and rank the four manufacturing cells on the basis of lean assessment: material flow, visual control, and metrics. Each parameter for lean assessment is compared against every other parameter with Satty`s intensity table with five expert members to remove any sort of bias. The comparison matrix of the parameters hence obtained is shown in table 1 below.

Table 1: Comparison Matrix of Parameters

Parameters for Lean Performance Assessment	Material Flow	Visual Control	Metrics
Material Flow	1	1/2	3
Visual Control	2	1	4
Metrics	1/3	1/4	1

Now consider the equation $[A.x = \lambda max.x]$ where, A is the comparison matrix of size n×n, for n criteria, also called the priority matrix. X is the Eigenvector of size n× 1, also called priority vector. λmax is the Eigenvalue. Further, we need to find the ranking of priorities, i.e., the Eigenvector. The first step is to normalize the column entries by dividing each entry by the sum of the respective columns. Then we take the overall row average.

$$A = \begin{bmatrix} 1 & 0.5 & 3 \\ 2 & 1 & 4 \\ 0.33 & 0.25 & 1 \end{bmatrix} \xrightarrow{\text{Normalized Column Sum}} \begin{bmatrix} 0.30 & 0.28 & 0.37 \\ 0.60 & 0.57 & 0.51 \\ 0.10 & 0.15 & 0.12 \end{bmatrix} \xrightarrow{\text{Row Averages}} x = \begin{bmatrix} 0.32 \\ 0.56 \\ 0.12 \end{bmatrix} \quad (1)$$

'A' is the comparison matrix of size (n×n) depending on the number of criteria. The Eigenvector, X obtained above indicates the weightage of various parameters. Visual control (0.56) is the most important criteria; Metrics (0.12) is the least important criteria while the material flow (0.32) is a criterion of intermediate importance.

$$\begin{bmatrix} 1 & 0.5 & 3 \\ 2 & 1 & 4 \\ 0.33 & 0.25 & 1 \end{bmatrix} \begin{bmatrix} 0.32 \\ 0.56 \\ 0.12 \end{bmatrix} = \begin{bmatrix} 0.98 \\ 1.68 \\ 0.36 \end{bmatrix} = \lambda max. \begin{bmatrix} 0.32 \\ 0.56 \\ 0.12 \end{bmatrix} \quad (2)$$

$\lambda max. = Avg.$ [0.98/0.32, 1.68/0.56, 0.36/0.12] =3.04

Checking for Consistency

The next step is to calculate the consistency ratio (CR) in order to measure how consistent the judgements have been relative to large samples of purely random judgements. AHP evaluations are based on the assumptions that the decision

maker is rational i.e., if A is preferred to B & B is preferred to C, then A is preferred to C. If the CR value is greater than 0.1 then the judgements are untrustworthy because they are too close for comfort to randomness and the exercise is valueless and must be repeated.

Calculation of Consistency Ratio

The next stage is to calculate λmax so as to lead to the consistency index & the consistency ratio.

Consider $[A.x = \lambda max.x]$ where, x is the Eigen vector.

This further results in-

$$\underset{A}{\begin{bmatrix} 1 & 0.5 & 3 \\ 2 & 1 & 4 \\ 0.33 & 0.25 & 1 \end{bmatrix}} \underset{X}{\begin{bmatrix} 0.32 \\ 0.56 \\ 0.12 \end{bmatrix}} = \underset{A.X}{\begin{bmatrix} 0.98 \\ 1.68 \\ 0.36 \end{bmatrix}} = \lambda max. \underset{X}{\begin{bmatrix} 0.32 \\ 0.56 \\ 0.12 \end{bmatrix}} \tag{3}$$

$$\text{Now,} \lambda_{max.} = \text{Avg.} \left[\frac{0.98}{.32}, \frac{1.68}{0.56}, \frac{0.36}{0.12}\right] = 3.04 \tag{4}$$

Consistency index (C.I) is found by the formula-

$$\text{C.I} = \frac{\text{Principal Eigen Value} - \text{Size of matrix}}{\text{Size of Matrix} - 1} = \frac{\lambda\,\text{max} - \text{n}}{\text{n} - 1} \tag{5}$$

$$\text{C.I} = \frac{(3.04-3)}{(3-1)} = 0.02$$

$$\text{Now, Consistency Ratio (C.R.)} = \frac{\text{Consistency Index}}{\text{Random Index}} = \frac{\text{C.I.}}{\text{R.I.}} \tag{6}$$

The value of R.I is found from the standard R.I table shown below in table 2.

Table 2: Random Index Table

n	1	2	3	4	5	6	7
R.I	0	0	0.52	0.88	1.11	1.25	1.35

From the above table R.I is found to be 0.52 when n is 3.

$$\text{Hence, C.R} = \frac{\text{C.I}}{\text{R.I}} = \frac{0.02}{0.52} = 0.04$$

It is found that the C.R value is 0.04 which is much below 0.1, which indicates that there is sufficient consistency for decision.

The next step is to use analytical hierarchical processing for ranking the four alternatives (manufacturing cells) for the three criteria. The ranking of the four alternatives for the criteria of material flow is done below as shown in table 3.

Table 3: AHP Ranking Alternatives

Material Flow	Mfg. Cell 1	Mfg. Cell 2	Mfg. Cell 3	Mfg. Cell 4
Mfg. Cell 1	1	0.25	4	0.167
Mfg. Cell 2	4	1	4	0.25
Mfg. Cell 3	0.25	0.25	1	0.20
Mfg. Cell 4	6	4	5	1
Column sum	11.25	5.5	14	1.61

$$\text{Normalized column sums - } \xrightarrow[\text{Priority Vector}]{\text{Row Average}}$$

$$\begin{array}{l} Mfp.Cell1 \\ Mfp.Cell\ 2 \\ Mfp.Cell3 \\ Mfp.Cell4 \\ column\ total \end{array} \begin{bmatrix} 0.088 & 0.0454 & 0.2857 & 0.1035 \\ 0.355 & 0.1818 & 0.2857 & 0.1552 \\ 0.022 & 0.0454 & 0.0714 & 0.1242 \\ 0.533 & 0.7272 & 0.3571 & 0.6211 \\ 1 & 1 & 1 & 1 \end{bmatrix} \text{X=} \begin{bmatrix} 0.1306 \\ 0.2444 \\ 0.0657 \\ 0.5596 \end{bmatrix}$$

In a similar way, the priority vectors are calculated for the two other parameters namely visual control and metrics. These two priority vectors are given below.

$$\text{Priority vector for visual control is, X=} \begin{bmatrix} 0.38 \\ 0.29 \\ 0.07 \\ 0.26 \end{bmatrix}$$

$$\text{\&, the priority vector for Metrics is, X=} \begin{bmatrix} 0.30 \\ 0.2389 \\ 0.2123 \\ 0.2477 \end{bmatrix}$$

Combining all these results we get the figure as shown below which gives the decision makers glimpse of the weightage gives to various criteria for different alternatives.

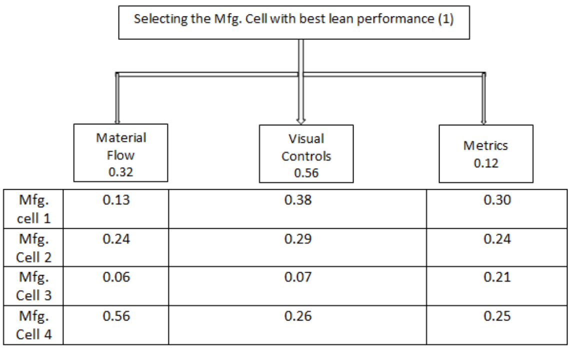

Figure 1: AHP (Ranking Alternatives)

The last step is to go for the pairwise comparison of each parameter of lean performance assessment is done for all four manufacturing cells in the company. The basic idea of comparing the manufacturing cells on some common uniform criteria can be served by using AHP as multi-attribute decision-making model which is used with individual lean radar charts. The final overall weights and ranking of manufacturing cells are below. The top manufacturing cell according to current assessment is the fourth on while the manufacturing cell which is at the bottom and requires maximum improvement is the manufacturing cell three.

$$\begin{array}{l} \\ Mfg.Cell\ 1 \\ Mfg.Cell\ 2 \\ Mfg.Cell\ 3 \\ Mfg.Cell\ 4 \end{array} \begin{array}{c} \text{Material Flow} \quad \text{Visual Control} \quad \text{Metrics} \\ \begin{bmatrix} 0.13 & 0.38 & 0.30 \\ 0.24 & 0.29 & 0.24 \\ 0.07 & 0.07 & 0.21 \\ 0.56 & 0.26 & 0.25 \end{bmatrix} \end{array} \times \begin{bmatrix} 0.32 \\ 0.56 \\ 0.12 \end{bmatrix} = \begin{bmatrix} 0.28 \\ 0.25 \\ 0.07 \\ 0.34 \end{bmatrix} \qquad (7)$$

Priority Matrix Criteria wt.

The priority matrix on being multiplied by the criteria weights gives us the final overall weights which gives us the ranking of the four manufacturing cells.

RESULTS AND CONCLUSIONS

The current research work presents a detailed approach to use the AHP methodology in order to compare and rank lean performances of four manufacturing cells in an SME. As it can be observed, AHP works perfectly as a multi-attribute decision-making tool when a number of alternatives are to be compared based on a number of parameters. The assessment of manufacturing cells based on lean performance enables comparison of cells and rank them on uniform criteria. The final overall as obtained above clearly indicate that the lean performance of the manufacturing cell no.4(overall wt. of 0.34) is the best while the manufacturing cell no. 3 has the maximum scope and need for improvement. Manufacturing cells 1 and 2 rank 3 and 4 respectively. It is finally proposed to compare rank the cells regularly at certain predetermined intervals. Also, the top manufacturing cell would be rewarded in order to create a sense of healthy competition and motivate all manufacturing cells to strive for continuous improvement.

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